TIDAL POWER STUDY

JUSKATLA NARROWS, QUEEN CHARLOTTE ISLANDS, B.C.

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Juskatla Narrows, B.C.

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QUEEN CHARLOTTE ISLANDS TIDAL POWER STUDY
JUSKATLA NARROWS OVERVIEW REPORT

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SUMMARY

The vertical axis hydraulic turbine (VAHT) is a relatively new concept for generating hydroelectric energy from fast flowing rivers or tidal currents. The concept has been under development by Nova Energy Ltd. of Dartmouth, Nova Scotia.

An overview study completed in 1983 by B.C. Hydro (Ref. 1) examined power supply options on the Queen Charlotte Islands (QCI) and identified Juskatla Narrows as a potential site for tidal power development. That study specifically recommended follow-up investigations of the feasibility of implementing a VAHT installation at Juskatla Narrows.

The current study was initiated in June 1983, to assess the technical and economic feasibility of a VAHT installation at Juskatla Narrows as a means to reduce diesel fuel consumption on the QCI. Because of the off-oil nature of the study, joint funding for the study was sought under the Remote Community Demonstration Program administered by Energy Mines and Resources, Canada. A joint funding agreement was completed in June 1983 which provided a total study budget of $45,000 shared on a 50/50 basis between B.C. Hydro and EMR Canada. Nova Energy Ltd. were the technical consultants for the study and they received $34,867.

The basic development concept examined in this study was a 1000 kW VAHT unit installed in the eastern portion of Juskatla Narrows. The unit was assumed to operate in the freestream mode, hence construction of a barrage in Juskatla Narrows or Canoe Passage would not be required. Transmission was assumed to be via 20 km of 3-phase, 25 kV line to link up with the existing circuit at Port Clements. An extension to the basic development would be to add two additional freestream units of similar design. Due to water blockage effects with three units in

Juskatla Narrows, the rated output of the units would be increased to 3600 kW (1200 kW per unit). Additional transmission facilities would likely be required if the second and third units were added.

The major fundings of the overview study of the proposed tidal installation are as follows:

1. A 1000 kW VAHT unit at Juskatla Narrows would have a capital cost of 8060 k$ (October 1983) excluding interest during construction. A three-unit VAHT installation would have a capital cost of 18 490 k$.

2. The average energy output of the proposed one and three-unit VAHT installations would be 3.46 and 12.5 GW·h/a, respectively which is equivalent to an annual capacity factor of 40 percent. The power output would fluctuate according to semi-diurnal tidal variations.

3. The proposed VAHT units would be physically large, having a rotor diameter of 9.75 m and a rotor blade length of 9.25 m.

4. Economic analysis indicates that VAHT generation would be substantially more costly than expected savings in diesel fuel. For example, annual diesel fuel savings for the 1000 kW VAHT were estimated to be 840 000 L which is equivalent to 283 k$ at 1983/84 diesel fuel prices (33.7 ¢/L). The corresponding annual costs for the VAHT unit were estimated to be 645 k$ at an interest rate of 4 percent/a net of inflation. Similar conclusions apply to the three-unit VAHT installation.

5. The proposed VAHT installation should not pose any significant control problems for the Masset diesel plant. The most significant effect of the VAHT units will be increased operation of the diesel units at lower capacity factors.

6. There are still significant uncertainties regarding the commercial feasibility of VAHT units. The principal issues which should be addressed in further technology development work are operational reliability, cost effectiveness and structural integrity.

7. No significant environmental impacts are anticipated and public reaction appears generally favourable. However, more detailed information on the effects of VAHT units on fish and marine mammals is required. In addition, careful attention to other environmental issues and discussions with the local public would be required if the project is to proceed.

Because of the technical uncertainties and indicated poor cost effectiveness of the proposed VAHT installation, it is recommended that B.C. Hydro not fund further major technology development studies of a potential VAHT development at Juskatla Narrows at this time. However, if a research agency (such as the Canadian Electrical Association or the National Research Council) agree to fund further studies, B.C. Hydro could consider offering some services in support of this work. These services could include obtaining site information (e.g. tidal current measurements, water samples, site surveying, etc.) or possibly providing in-house design expertise to review results of model and design studies.

Model studies could also examine potential impacts of VAHT units on fish and marine mammals, and B.C. Hydro could nominate staff to review and advise on such studies.

ETUDE SUR UNE MAREMOTRICE POUR LES ILES DE LA REINE-CHARLOTTE

JUSKATLA NARROWS (C.-B.)

Résumé pour la direction

La turbine hydraulique à axe vertical (THAV)* représente l'application d'une notion relativement nouvelle à la mise en valeur de l'énergie de courants de marée et de cours d'eau à écoulement rapide. La société Nova Energy Ltd. de Dartmouth (N.-E.) travaille depuis quelque temps à la mise au point de cette turbine.

Une étude globale menée par la B.C. Hydro avait examiné les options d'approvisionnement en énergie électrique offertes aux îles de la Reine-Charlotte et conclu que le chenal connu sous le nom de Juskatla Narrows est un site marémoteur potentiel. L'étude recommandait d'examiner de plus près la faisabilité d'implanter une installation THAV à Juskatla Narrows.

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* La turbine hydraulique à axe vertical est similaire, de par son principe de fonctionnement, à la turbine éolienne à axe vertical ou rotor Darrieus. Le rotor est constitué d'aubes (habituellement au nombre de quatre) reliées par des bras à un arbre. Les aubes sont de profil symétrique, à fort coefficient de portance et à faible coefficient de traînée. En raison des caractéristiques hydrodynamiques particulières des aubes, leur rotation dans un écoulement d'eau applique un couple accélérateur sur l'arbre du rotor. Le couple est transmis par l'arbre à une boîte d'engrenage multiplicateur qui entraîne un générateur d'électricité. Pour accroître la puissance de sortie d'une installation THAV, on peut y incorporer une structure à conduits qui augmente la superficie en profil de l'installation et par conséquent, la puissance de sortie. Les conduits peuvent servir en même temps de support structural au rotor.

L'intérêt principal des THAV découle du fait qu'elles peuvent fonctionner comme dispositifs pour exploiter l'énergie des sites à très faible hauteur de chute et permettre ainsi la production d'électricité à même les cours d'eau et les courants de marée à faible hauteur de chute, et ce de façon économique. La THAV peut s'exploiter soit au fil de l'eau aux sites où le débit de la rivière ou de la marée dépasse 2 m/s, soit aux sites à faible hauteur de chute dans un barrage. Dans ce dernier cas, la gamme des hauteurs de chute exploitables se situe entre 0,5 et 3,0 m. La Nova Energy Ltd. indique que les installations au fil de l'eau d'une puissance entre 10 kW et 1000 kW, ainsi que les installations à faible hauteur de chute d'une puissance entre 100 kW et 20 MW, semblent faisables. Ces installations pourraient éventuellement s'implanter à divers sites fluviaux et marémoteurs le long de la côte de la Colombie-Britannique, y compris celui de Juskatla Narrows.

La B.C. Hydro a par conséquent entrepris la présente étude pour évaluer la faisabilité technique et économique d'aménager une centrale THAV au site de Juskatla Narrows, et ce afin de réduire la consommation de carburant diesel dans les Îles de la Reine-Charlotte. En raison de l'objectif de remplacement du pétrole que se donnait le projet, l'étude a été financée conjointement par le Programme de démonstration dans les collectivités éloignées, administré par Energie, Mines et Ressources Canada, et par la B.C. Hydro. La Nova Energy Ltd. a participé à l'étude à titre d'expert-conseil technique et a reçu une tranche de 34 867 $ du budget total de 45 000 $ attribué à l'étude.

L'option d'aménagement examinée par l'étude est celle de l'implantation d'une THAV d'une puissance de 1000 kW dans la partie est de Juskatla Narrows. On a adopté l'hypothèse de l'exploitation au fil de l'eau; la construction d'un barrage à Juskatla Narrows ou à Canoe Passage ne serait donc pas nécessaire. Le transport d'énergie serait assuré par une ligne triphasée de 25 kV d'une longueur de 20 km reliant l'installation prévue au réseau existant à Port Clements. On pourrait accroître la puissance installée par l'ajout de deux turbines de conception similaire. A cause d'effets de restriction avec trois groupes installés à Juskatla Narrows, la puissance nominale des trois groupes serait portée à 3600 kW (1200 kW par groupe). Il faudrait probablement prévoir des moyens additionnels de transport si les deuxième et troisième turbines étaient installées.

Les principales constatations de l'étude sont les suivantes:

1. Un groupe THAV de 1000 kW à Juskatla Narrows représente un coût en capital de 8 060 000 $ (octobre 1983), en ne tenant pas compte des intérêts pendant la phase de construction. Le coût en capital d'une installation à trois groupes s'élèverait à 18 490 000 $.

2. La production moyenne annuelle d'énergie des installations proposées serait de 3,46 GW.h pour un groupe et de 12,5 GW.h pour les trois. Il y aurait une fluctuation de la puissance de sortie en fonction des variations semi-diurnes de la marée.

3. L'encombrement des groupes THAV proposés serait important: le diamètre du rotor serait de 9,75 m et la longueur des aubes de 9,25 m.

4. L'analyse économique indique que cette filière de production d'énergie électrique entraîne des coûts sensiblement supérieurs à ceux de l'option diesel. Par exemple, dans le cas de la turbine hydraulique de 1000 kW, on peut prévoir des économies de carburant diesel d'environ 840 000 L, ce qui représente 283 000 $ aux prix actuels (1982-1983) du carburant diesel (33,7 ¢/L). Le coût annuel d'exploitation de l'installation proposée s'élèverait à 645 000 $. Pour l'option trois turbines, les conclusions sont semblables.

5. L'installation proposée ne poserait aucun problème important de fonctionnement à la centrale diesel de Masset. L'effet le plus important de la mise en service des groupes THAV serait d'accroître l'exploitation des groupes diesel à des coefficients d'utilisation faibles.

6. Il reste encore des incertitudes de taille quant à la rentabilité des installations THAV. Les principales questions à étudier lors de travaux ultérieurs de mise au point technique sont la fiabilité d'exploitation, la rentabilité et l'intégrité structurale.

7. Aucune incidence environnementale sensible n'a été repérée; la réaction du public semble en général favorable au projet. Il faut obtenir toutefois des données plus détaillées sur les effets éventuels des THAV sur les poissons et les mammifères marins. Il faudrait se soucier aussi tout spécialement des autres préoccupations d'ordre environnemental et obtenir les réactions et les suggestions du public local, au cas où le projet serait réalisé.

En raison des incertitudes techniques et de la piètre rentabilité de l'installation proposée à turbines hydrauliques à axe vertical, l'expert-conseil ne recommande pas à la B.C. Hydro de financer d'autres grandes études de développement technique relatives à l'implantation éventuelle de groupes THAV au site de Juskatla Narrows. Toutefois, si un organisme axé sur la recherche, tel que l'Association canadienne de l'électricité ou le Conseil national de recherches, acceptait de financer d'autres études, la B.C. Hydro serait disposée à examiner la possibilité d'offrir certains services pour appuyer de tels travaux ultérieurs. Ces services pourraient inclure la collecte de données sur place (mesure des courants de marée, échantillonnage d'eau, levés) et peut-être de mettre à la disposition de ces organismes les compétences en études techniques de la société pour l'examen des résultats de la modélisation et des études techniques.

La modélisation pourrait aussi servir à l'examen des effets éventuels des turbines hydrauliques à axe vertical sur les poissons et les mammifères marins; la B.C. Hydro serait disposée à affecter des membres de son personnel à l'examen de telles études et à fournir des conseils dans ces domaines.

SECTION 1.0 - INTRODUCTION

1.1 BACKGROUND

The Queen Charlotte Islands (QCI) are located about 100 km off the north coast of B.C. (Fig. 1-1). The two main islands, Graham and Moresby, are separated by the Skidegate Channel. There are six major communities on the Islands (Masset, Queen Charlotte City, Sandspit, Port Clements, Skidegate and Tlell) and the total population is about 5400 persons.

Electric power for the QCI communities is supplied by diesel generating stations located at Masset and Sandspit which are owned and operated by B.C. Hydro. The total B.C. Hydro electrical generation in the QCI during the 1983/84 fiscal year was 36.1 GW·h which was produced from 10.9×10^6L of diesel fuel. Annual fuel costs of $3.7 million represented about 75 to 80 percent of the total annual operating cost.

Rapid escalation in the price of diesel fuel over the past 10 years has focused increasing attention on alternatives to diesel generation in the QCI and other diesel service areas. In 1980 B.C. Hydro undertook a comprehensive in-house study to examine options for supplying existing and future electrical loads on the QCI (Ref. 1). This study was completed in 1983 and it outlined several alternatives which appeared to warrant further investigation as options to displace or supplement existing diesel generation (see Section 1.5).

The QCI power supply study included a preliminary review of tidal resources in the area. The study identified six potential sites (i.e. Masset Sound, Juskatla Narrows, Alexandra Narrows, Long Inlet, Van Inlet and Atli Inlet) and suggested that Juskatla Narrows could be an attractive site for the installation of high flow, low head turbines

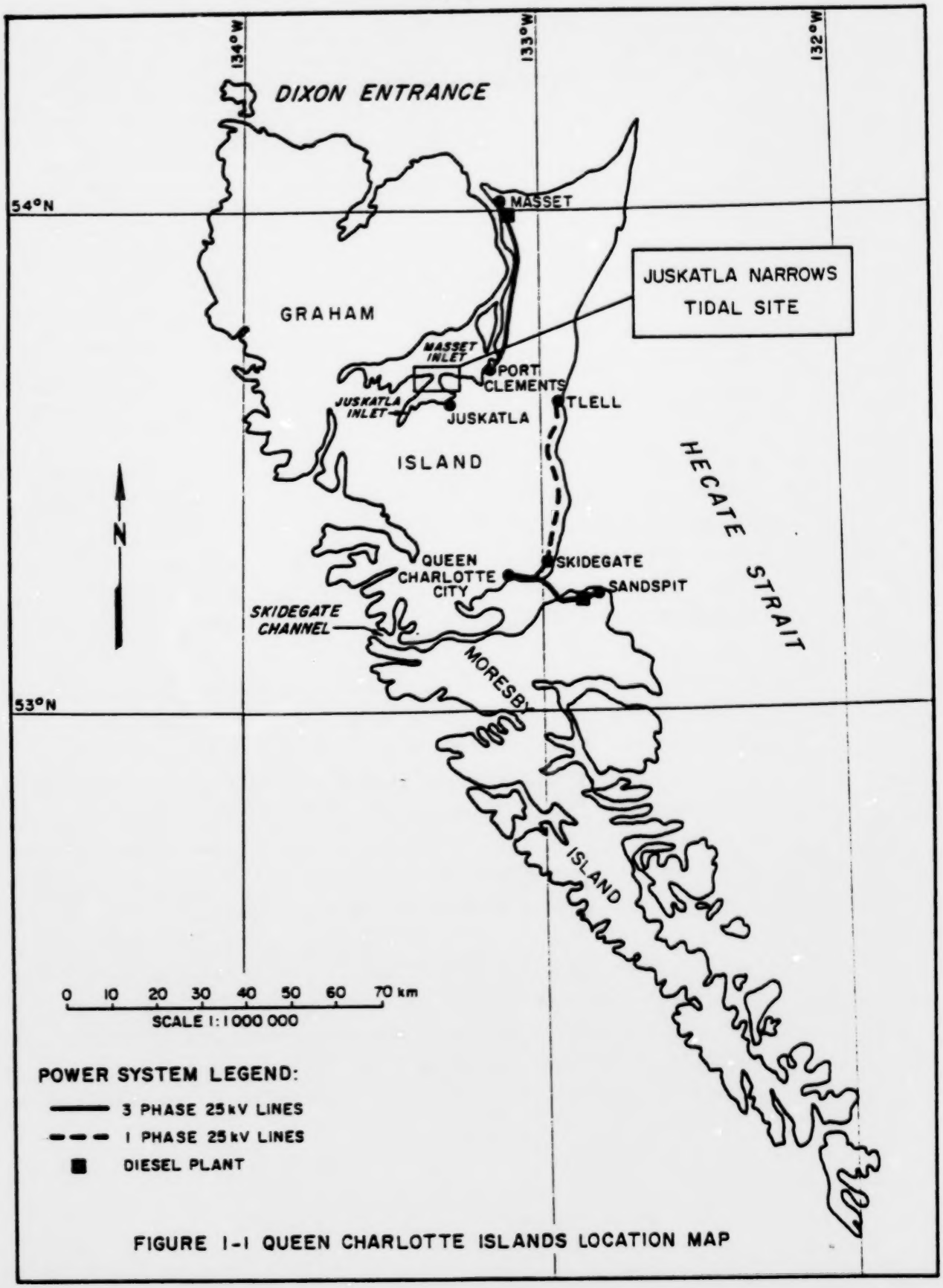


FIGURE 1-1 QUEEN CHARLOTTE ISLANDS LOCATION MAP

such as the VAHT units (vertical axis hydraulic turbine) being developed by Nova Energy Ltd. of Dartmouth, N.S.

In early 1983 B.C. Hydro and Nova Energy submitted a joint study proposal to Energy, Mines and Resources Canada to conduct a feasibility assessment of a VAHT development at the Juskatla Narrows (Ref. 4). The study proposal sought co-funding under the Remote Community Demonstration Program. The proposal was subsequently accepted and an agreement to proceed with the study was finalized in June 1983. Under the terms of the agreement, the total study budget of $45,000 was to be split 50/50 between EMR and B.C. Hydro. Nova Energy was retained as technical consultants for the study and received $34,867 of the budget. The balance was to cover B.C. Hydro expenses.

1.2 STUDY OBJECTIVES

The basic objective of the study was to determine the technical and economic feasibility of developing tidal power generation at Juskatla Narrows to offset consumption of diesel fuel. Technical aspects of the study relating to design, performance analysis and cost estimates for VAHT generating units were conducted and reported by Nova Energy Ltd. (Ref. 2). Aspects of the study carried out by B.C. Hydro included transmission requirements, effects on diesel plant operation, economic evaluation, environmental and socio-economic impacts.

1.3 EXISTING QCI POWER SYSTEM

The QCI power system consists of two diesel generating stations and associated distribution circuits as shown in Fig. 1-1. The two systems are not interconnected.

The Masset diesel station is the larger of the two and serves the communities of Masset and Port Clements. The generating station comprises five units with a total capacity of 9400 kW (Table 1-1). In 1983/84 the peak and energy loads on the Masset system were 3610 kW and 19.3 GW·h, respectively. Typical daily load curves for the Masset system in 1982/83 are shown in Fig. 1-2.

The Sandspit diesel station serves the communities of Sandspit, Queen Charlotte City, Skidegate and Tlell. The latter three communities receive power via a 25 kV submarine cable across Skidegate Inlet. The generating station comprises seven units having a total capacity of 6800 kW (Table 1-1). In 1983/84 the peak and energy loads on the Sandspit system were 3700 kW and 18.2 GW·h, respectively. Typical daily load curves for the Sandspit system in 1982/83 are shown in Fig. 1-3.

Fuel oil consumption and other operating data for the Masset and Sandspit diesel stations in 1983/84 are shown in Table 1-1. These data show that the 1983/84 unit fuel costs at the Masset and Sandspit diesel stations were 97 and 99 mills/kW·h, respectively.

1.4 FUTURE LOAD GROWTH

Projections of future load requirements for the Masset and Sandspit systems are shown in Table 1-2. These projections are based on the assumption that B.C. Hydro would continue to supply only residential and commercial demand. The existing diesel capacity at Masset would be adequate to handle projected growth on that system to 1990. For Sandspit, additional diesel capacity would be required in 1988/89 (e.g. addition of a 600 kW road mobile unit).

Currently, the only significant industrial load on the QCI is the MacMillan Bloedel logging operation at Juskatla (peak of approximately 300 kW) which is supplied by their own diesel generators.

FIGURE 1-2
PASSET DGS - TYPICAL DAILY LOAD CURVES
1982 83 FISCAL YEAR

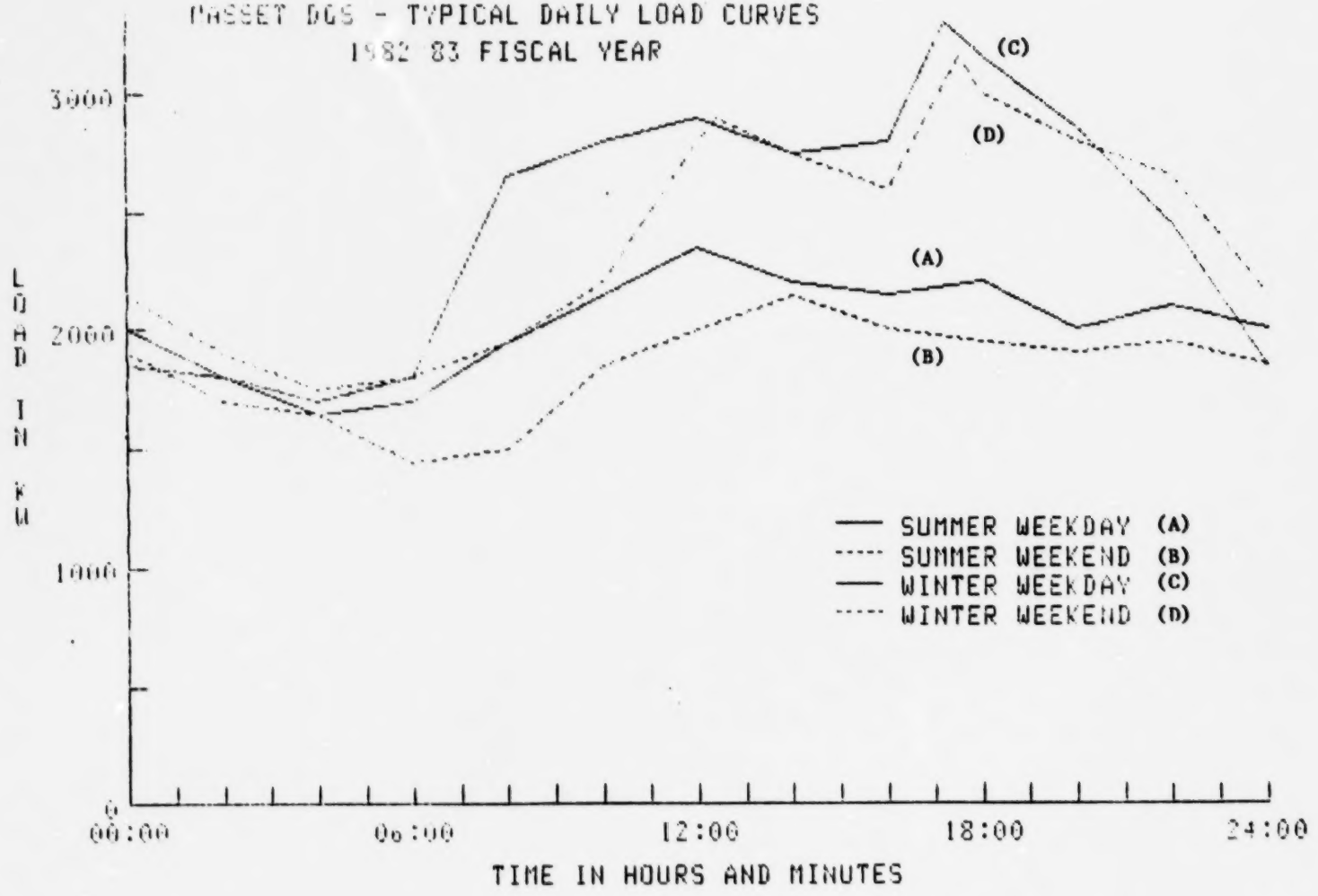


FIGURE 1-3
SHADSPIT DGS - TYPICAL DAILY LOAD CURVES
1982-83 FISCAL YEAR

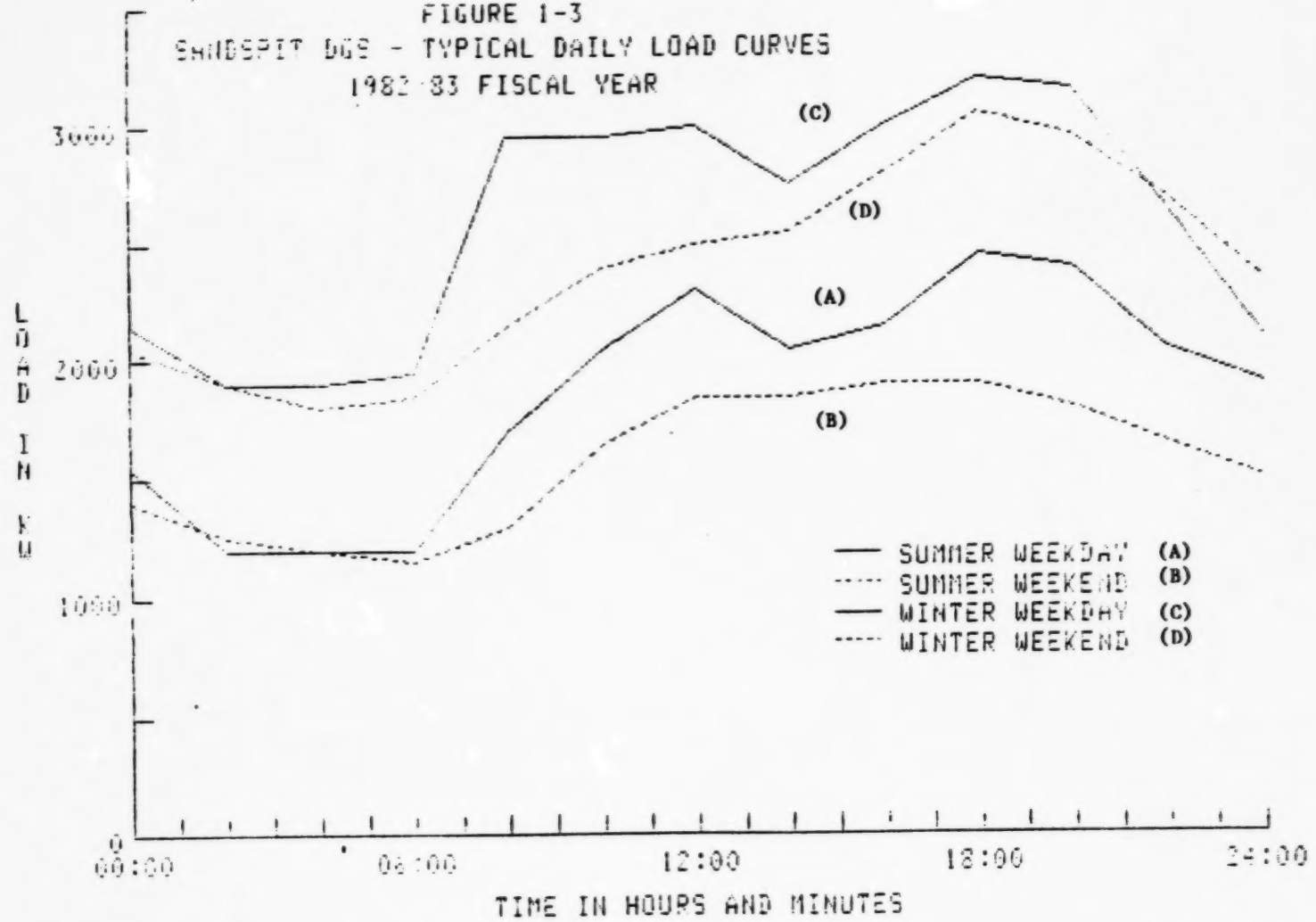


TABLE 1-1

MASSET AND SANDSPIT DIESEL PLANT DATA

	Masset	Sandspit
1. Powerplant Data		
Generating capacities*1		
- Stationary	6 300 kW (3 units)	3 700 kW (5 units)
- Mobiles	3 100 kW (2 units)	3 100 kW (2 units)
- Total	9 400 kW (5 units)	6 800 kW (7 units)
Fuel efficiency	3.5 kW·h/L	3.4 kW·h/L
Fuel storage	540 000 L	468 000 L
2. Annual Operating Data*2		
Energy generated	19.3 GW·h	18.2 GW·h
Fuel consumption	5 528 000 L	5 343 000 L
Operating costs (k$)		
- Fuel	1 870	1 810
- Other	620	470
- Total	2 490	2 280
Unit energy costs (mills/kW·h)		
- Fuel	97	99
- Other	32	26
- Total	129	125

*1 As at September 1983.

*2 For fiscal year 1983/84.

TABLE 1-2

MASSET AND SANDSPIT PRELIMINARY LOAD FORECASTS

(July 1984)

Fiscal Year	Masset		Sandspit	
	Peak (kW)	Energy (GW·h)	Peak (kW)	Energy (GW·h)
83/84 (actual)	3610	19.3	3700	18.2
84/85	3800	20.1	3900	19.1
85/86	3900	21.1	4090	20.2
86/87	3960	21.7	4170	20.8
87/88	4020	22.2	4255	21.3
88/89	4100	22.8	4340	21.9
89/90	4180	23.4	4425	22.5
Average annual growth rate	2.47%	3.29%	3.03%	3.57%

The main potential for industrial load growth on the QCI appears to be in the mining sector. Consolidated Cinola Mines Ltd. has a prospective gold property south of Juskatla Inlet, and development proposals indicate up to 41 MW of electric power would be required. The mine has a minimum projected life of 10 years. There appears to be other significant mineral deposits on the QCI (Ref. 1, Appendix C), but there are no firm plans for any new mines at this stage. Other possible industrial developments on the QCI include peat excavation and processing, offshore oil exploration (Hecate Strait) and additional forestry operations.

1.5 POWER SUPPLY OPTIONS

The earlier QCI power study (Ref. 1) identified possible electrical energy supply options to reduce diesel fuel consumption at existing or future diesel plants and provide firm generation for new industrial loads.

Options which appeared to have the best potential as diesel fuel-savers were gas turbines operating on gasified waste wood, wind, tidal (Juskatla Narrows) and small hydro (Ain River). Other options which appeared attractive to supply firm power to possible large industrial loads included additional diesel plants, steam thermal plants (coal, peat or wood fuel) and submarine cables from the mainland.

Because of the intermittent nature of tidal generation, it cannot be considered a firm energy source. Energy storage systems (e.g. hydro-electric pumped storage) are a possible way of providing firm generation from tidal resources, but such schemes are unlikely to be cost competitive on small scale projects.

For the purpose of this study it is assumed that tidal generation at Juskatla Narrows would be implemented only to reduce diesel fuel

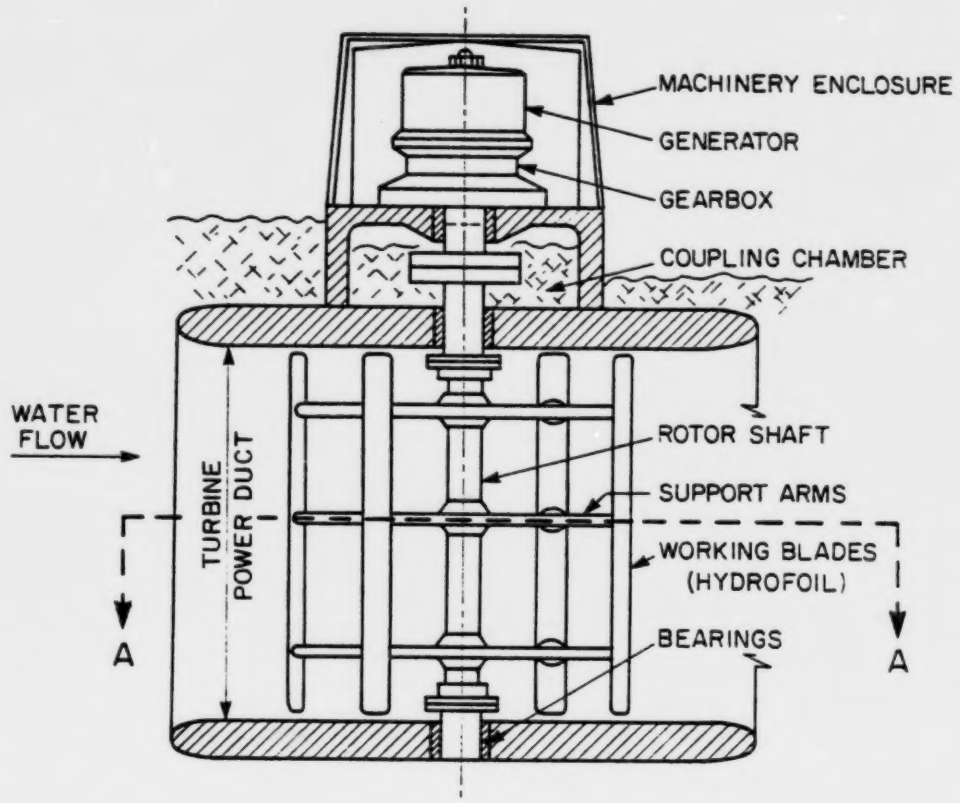
consumption. Consequently, the ultimate capacity of the proposed tidal development would be limited, not only by the site potential, but also by the ability of existing and planned diesel units to act as back-up generation during slack tide periods.

1.6 VAHT GENERATION TECHNOLOGY

The vertical axis hydraulic turbine (VAHT) is similar in principle to the vertical axis wind turbine (VAWT) or Darrieus rotor. Development of VAHT units has been pioneered by Nova Energy Ltd. of Dartmouth, N.S. The design and operation of VAHT units are discussed in several reports prepared by Nova (Refs. 2,3). A brief summary of the basic principles and development of VAHT units is included here for convenience.

Fig. 1-4 shows the basic components of a VAHT unit. The rotor consists of working blades (typically 4 blades) connected to a shaft by support arms. The blades are hydrofoils with a symmetrical cross section and have high lift and low drag coefficients. The hydro-dynamic characteristics of the blades are such that rotation of the blades in a flowing stream of water causes an accelerating torque to be generated on the rotor shaft (Ref. 2, Section 2.1). This torque is transmitted via the shaft to a step-up gear box which drives an electrical generator. To increase the power output of a VAHT unit, a duct structure can be incorporated which effectively increases the cross-sectional area of the unit and power output of the unit. The duct also provides structural support for the rotor.

The basic attraction of VAHT units is that they can operate as ultra low head devices which may permit the economic extraction of low head energy from rivers or tidal currents. VAHT's can be operated either as freestream devices at locations where river or tidal currents exceed 2 m/s, or as restricted flow (low head) devices incorporated in some form of barrage. In the restricted flow mode, the units would have an



PLAN SECTION A-A

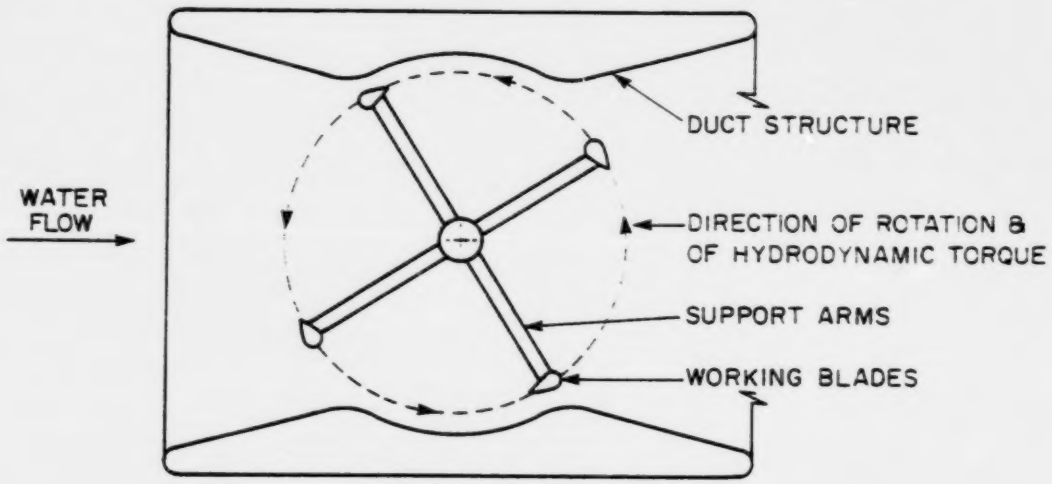


FIGURE 1-4 VERTICAL AXIS HYDRAULIC TURBINE BASIC DESIGN

operational head range of 0.5 to 3.0 m. Nova Energy indicate that freestream units with capacities in the range of 10 to 1000 kW, and restricted flow units with capacities in the range of 100 kW to 20 MW appear feasible. Such units could have applications at various river or tidal sites on the B.C. Coast, including Juskatla Narrows. Specific advantages of VAHT units for potential tidal or river applications are discussed in Ref. 2, Section 2.2.

Development work by Nova to date on VAHT units has been limited. Model tests have been conducted at the NRC Hydraulics Laboratory in Ottawa, and field tests of two small prototype units have been carried out. The first prototype was a 20 kW freestream unit (2.4 m rotor diameter) which was installed in the St. Lawrence River near Cornwall, Ontario and operated during the summer of 1982 (Ref. 4). The second prototype was a 100 kW restricted flow unit which was installed in an existing dam structure (3 m head) at Sheet Harbour, Nova Scotia. The unit began operation in June 1983, but the tests were interrupted due to cavitation damage to the duct structure.

At this stage of development, VAHT generators cannot be considered a commercial technology. Further modelling research and prototype tests appear necessary to determine the feasibility of large VAHT systems in terms of operational reliability, cost effectiveness and structural integrity.

SECTION 2.0 - PROJECT DESCRIPTION

2.1 SITE DESCRIPTION

Juskatla Inlet is located at the south end of Masset Inlet near the centre of Graham Island. Juskatla Inlet has an open water area of approximately 35 km^2 at low tide. The proposed location for tidal power development is Juskatla Narrows, the main entrance to Juskatla Inlet. Geographic details of the Narrows and environs are shown in Fig. 2-1.

Juskatla Narrows has a minimum width of 140 m and the water depth is 9 to 12 m in the main part of the channel. Canoe Passage, on the east side of Fraser Island, is a relatively shallow secondary entrance to Juskatla Inlet (i.e. average depth of 3 m). The bottom in Juskatla Narrows consists of scoured bedrock and is relatively flat in the eastern half of the channel.

Tidal action causes a considerable water volume flow in and out of Juskatla Inlet. Most of this flow passes through the Narrows (e.g. 85 to 90 percent goes through the Narrows, 10 to 15 percent goes through Canoe Passage). Tidal currents in the Narrows are strong (e.g. 2.1 to 3.1 m/s) and slack water periods between flood and ebb currents last only about 10 to 20 minutes. The tidal range at Juskatla Narrows is relatively small in comparison to other QCI locations (Table 2-1).

Navigation through Juskatla Narrows is limited due to the strong tidal currents and the presence of a shoal about 500 m south of the Narrows. The shoal limits passage to vessels having a draft of less than 2.4 m. Canoe Passage is not used for navigation due to very shallow water and the presence of large kelp beds.

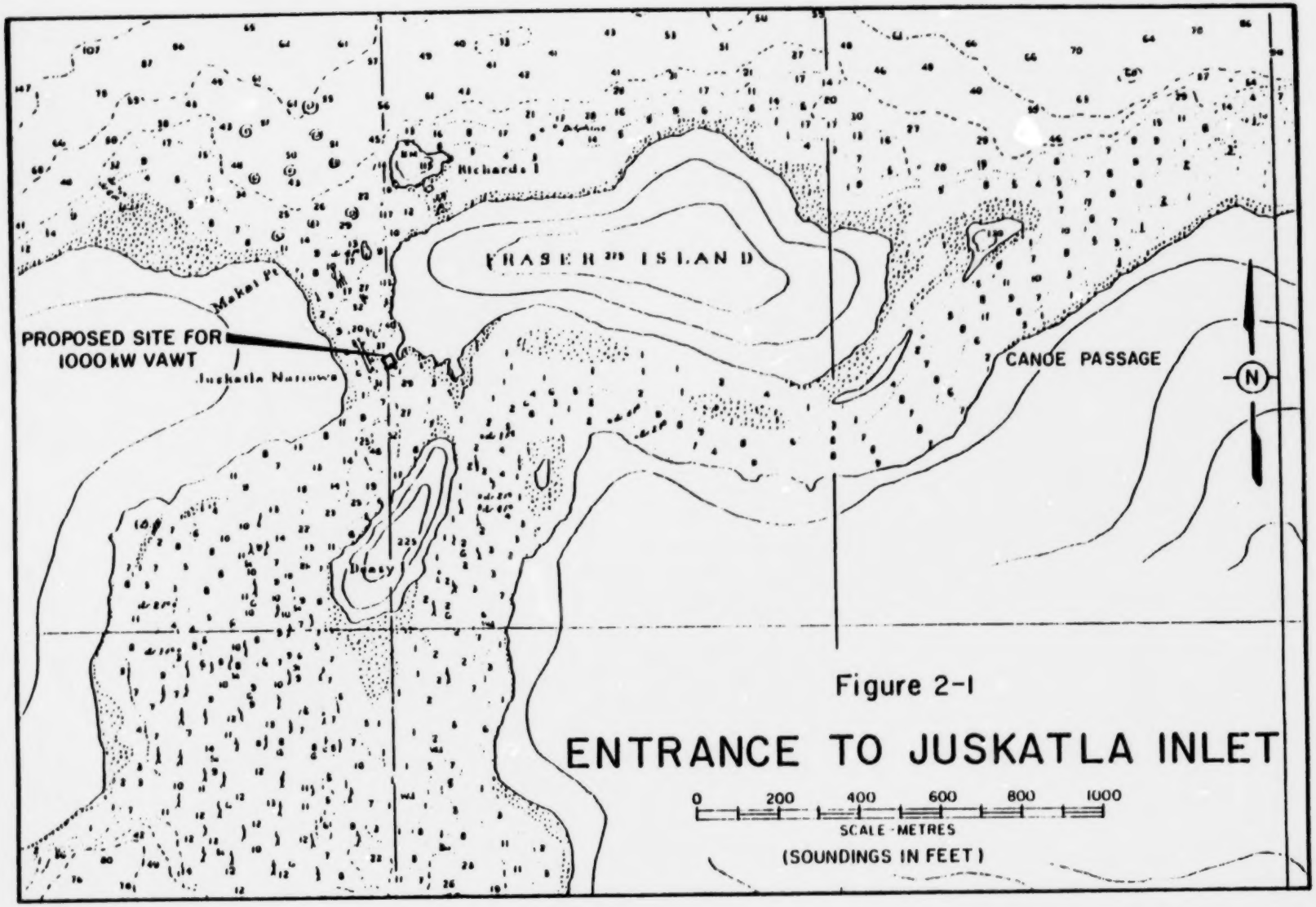


Figure 2-1

ENTRANCE TO JUSKATLA INLET

TABLE 2-1

QUEEN CHARLOTTE ISLANDS
MEAN TIDAL RANGE AT VARIOUS LOCATIONS

	Location	Mean Tidal Range (m)
1.	QCI - East Region	
	Rose Harbour	3.3
	Copper Islands	3.6
	Section Cove	4.1
	Sedgewick Bay	3.8
	Pacofi Bay	4.1
	Shingle Bay	5.2
	Queen Charlotte	5.1
2.	QCI - North Region (Dixon Entrance)	
	Masset	2.9
	Port Clements	2.2
	Juskatla	1.2
	Wiah Point	3.9
	Solide Passage	3.6
	McPherson Point	3.4
	Langara Point	3.5
	Juskatla Narrows	1.7

From: Pacific Coast Tide Tables, Canadian Hydrographic Service.

Currently, there is no road access to Juskatla Narrows but logging roads extend to within 2 km east and south of the site. MacMillan Bloedel are carrying out active logging on the east side of Juskatla Narrows and the main base for these operations is Juskatla (8 km southeast of the Narrows). The logs are hauled to the Ferguson Bay land sort area located 4 km east of the Narrows. MacMillan Bloedel also have timber licences on the west side of Juskatla Inlet, but there is currently no road access to this area. Road access would require construction of bridges across Juskatla Narrows and Canoe Passage. Preliminary designs for these bridges have been prepared, but there are no immediate plans to proceed with their construction. The site for the proposed bridge is essentially the same as that for the tidal development, and there appears to be a possibility of coordinated development. This aspect is discussed in Section 2.4.

2.2 DEVELOPMENT CONCEPTS

For the purpose of the overview assessment, tidal development of Juskatla Narrows is assumed to proceed in stages. The initial stage is assumed to comprise a single 1000 kW VAHT unit operating in the freestream mode (i.e. no barrage in either Juskatla Narrows or Canoe Passage). A detailed description of the proposed installation is presented in Section 5.0 of the Nova report. A preliminary layout sketch for the proposed initial 1000 kW development stage is shown in Fig. 2-2. The basic dimensions of the unit would be 22 m long, 15 m wide and 15 m high (excluding generator housing). The turbine rotor would have a diameter of 9.75 m and a blade length of 9.25 m. Nova have assumed the rotor would operate at a constant angular speed of 20 rpm, and that a gearbox would be used to step up the generator drive to 450 rpm. The peak generator output would be 1000 kW. Reasons for selecting a 1000 kW unit size were the following:

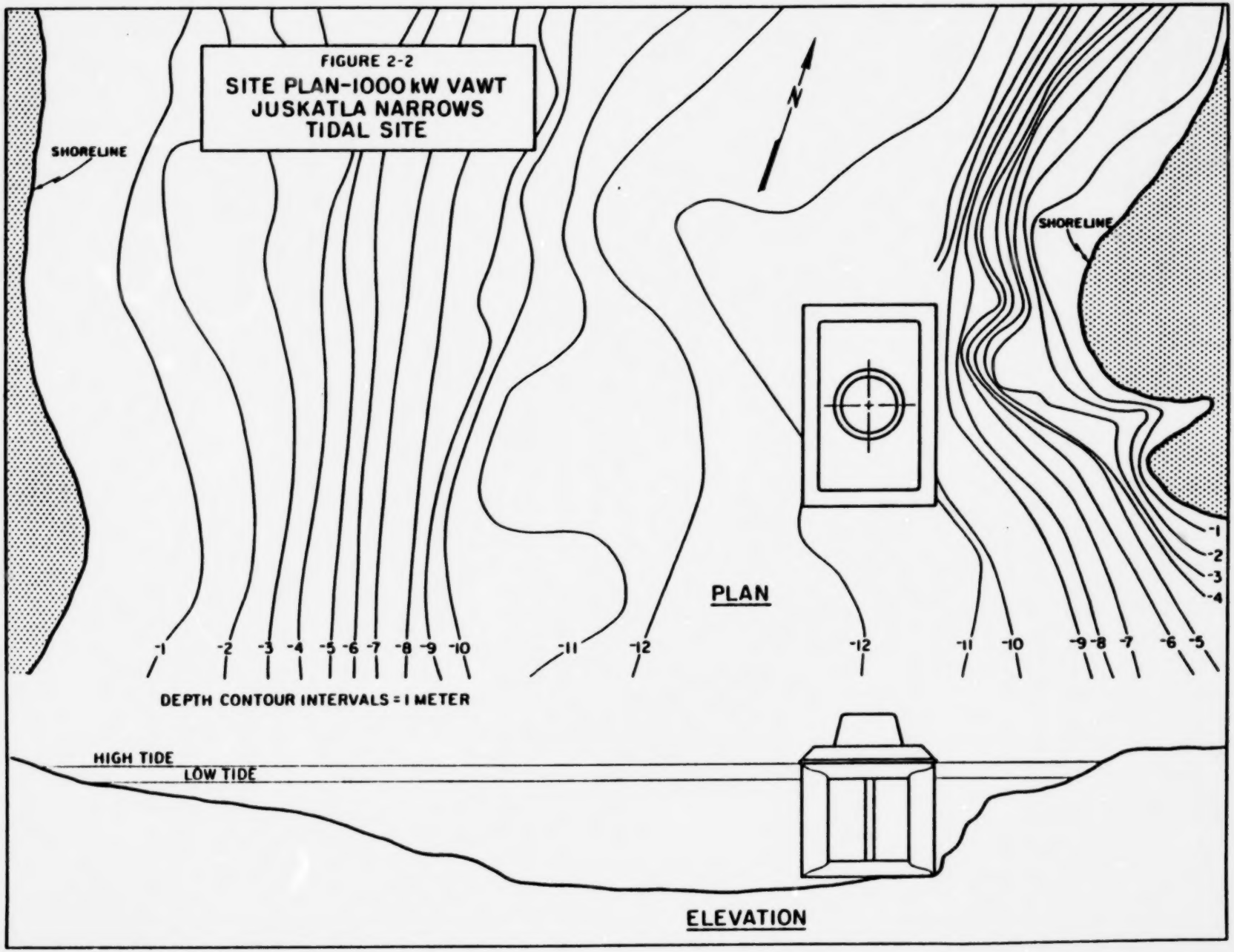


FIGURE 2-2
SITE PLAN-1000 kW VAWT
JUSKATLA NARROWS
TIDAL SITE
SHORELINE
SHORELINE
N
-1 -2 -3 -4 -5 -6 -7 -8 -9 -10 -11 -12
-12 -11 -10 -9 -8 -7 -6 -5
-1
-2
-3
-4
PLAN
DEPTH CONTOUR INTERVALS = 1 METER
HIGH TIDE
LOW TIDE
ELEVATION

1. All of the tidal unit output could probably be utilized on the Masset grid since the Masset base load rarely goes below 1500 kW.

2. Although the tidal unit would be physically large (i.e. 9.75 m rotor diameter), Nova have indicated that there do not appear to be any substantial design problems.

3. The energy capability of a 1000 kW unit could reduce diesel fuel consumption at the Masset diesel plant by a significant amount (e.g. 15 to 20 percent of annual consumption).

4. Nova have indicated that there are significant cost advantages in going to larger unit sizes (i.e. a 100 kW unit would have unit capacity costs about 20 to 30 percent greater than a 1000 kW unit).

Second and third VAHT units of similar capacity could be added at later stages. These additions would be subject to satisfactory performance of the initial unit and assessment of the need for additional tidal generation. Nova have indicated that the peak output of the 3-unit installation would probably be increased by 20 percent (i.e. from 3000 kW to 3600 kW) due to blockage or restricted flow effects (Ref. 2, Section 4.0).

The original concept for tidal development of Juskatla Narrows (Ref. 4) was for a restricted flow (barrage) rather than a freestream installation. Nova now indicate that a barrage scheme would not be economically feasible due to the low tidal range and the cost of civil works required in Juskatla Narrows and Canoe Passage. Consequently, the study focus has been generally on the freestream development concept, and specifically on the proposed initial 1000 kW installation.

2.3 TRANSMISSION REQUIREMENTS

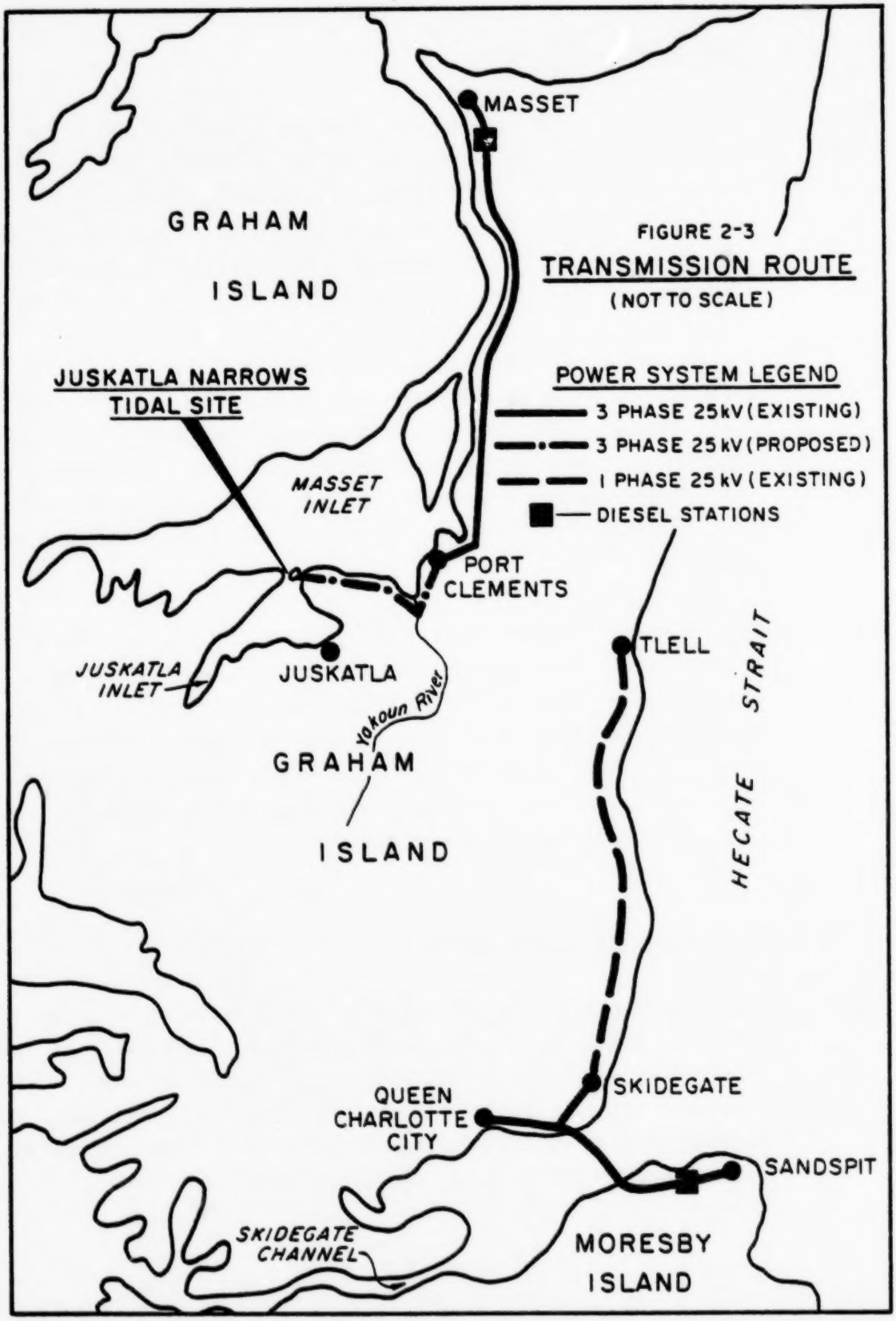
To integrate the proposed tidal plant to the Masset grid, the minimum transmission required would be 20 km of 3-phase, 25 kV line from Juskatla Narrows to Port Clements. A proposed route for this line is shown in Fig. 2-3. The route would generally run parallel to existing logging roads. Two water crossings (approximately 300 m each) would be required, one over Canoe Passage and the other over the Yakoun River.

The line to Port Clements should be adequate to carry the output of the proposed 1000 kW tidal unit although protection systems for single-phase loads on the circuit between Port Clements and Masset may have to be modified. If the second and third tidal units are added, further transmission additions would be required (e.g. an express 25 kV circuit from the tidal plant to Masset or integration of the Masset and Sandspit grids).

For the initial 1000 kW unit a 2.4/25 kV transformer and 25 kV circuit breaker would be required at the tidal plant. For the ultimate development of three units, it is assumed that the 25 kV circuit would be extended from Pt. Clements as an express feeder to the Masset diesel plant. Additional station facilities assumed are two transformers and circuit breakers at the tidal plant plus a circuit breaker and line connection at the Masset diesel plant.

2.4 INTEGRATION WITH BRIDGE DESIGN

MacMillan Bloedel have investigated construction of a bridge across Juskatla Narrows to provide access to timber leases west of Juskatla Inlet. The preliminary design for the bridge is a concrete box beam structure with a span of about 140 m (i.e. the full width of the Narrows). Piers would be located above high water marks on the east and west shores of the Narrows. At centre span the bridge would provide


MASSET
GRAHAM
ISLAND
FIGURE 2-3
TRANSMISSION ROUTE
(NOT TO SCALE)
JUSKATLA NARROWS
TIDAL SITE
POWER SYSTEM LEGEND
3 PHASE 25kV (EXISTING)
3 PHASE 25 kV (PROPOSED)
1 PHASE 25 kV (EXISTING)
DIESEL STATIONS
MASSET
INLET
PORT
CLEMENTS
TLELL
HECATE STRAIT
JUSKATLA
INLET
JUSKATLA
Yakoun River
GRAHAM
ISLAND
SKIDEGATE
QUEEN
CHARLOTTE
CITY
SANDSPIT
SKIDEGATE
CHANNEL
MORESBY
ISLAND

about 19 m of clearance above normal high water to meet expected requirements under the Navigable Waters Protection Act. Preliminary cost estimates for the bridge were between $10 and $20 million.

Nova Energy have carried out a preliminary assessment of the relationship between the proposed VAHT tidal installation and the bridge (Ref. 2, Section 9.0). Indications are that the VAHT units could serve as intermediate supports to reduce span lengths and costs for the bridge. No significant structural modifications to the VAHT units would be required to provide bridge support. With three VAHT units installed, the main span length could be reduced from 145 m to about 45 m. Also, less expensive truss-type construction could be employed for the bridge. Nova estimate that an overall cost saving of $5 to $7 million could be realized if the development of the VAHT and bridge installations were coordinated.

Plans for the bridge and the VAHT tidal installations have not advanced sufficiently to judge whether a coordinated development would be a realistic possibility. Consequently, the economics of the proposed VAHT tidal installation have been assessed independently of potential capital cost savings which might be attributable to a coordinated VAHT/bridge development.

2.5 ENERGY OUTPUT

The energy output from the proposed 1000 kW VAHT unit will vary with tidal conditions. For an average tide the unit would generate power for about 3 hours 45 minutes on both the flood and ebb. The total energy output over one complete average flood and ebb cycle is estimated to be 4900 kW·h (Ref. 2, Section 4.0). The corresponding average annual energy production would be 3.46 GW·h/a. Figs. 2-4, 2-5 and 2-6 show variations in the daily output of the VAHT unit under different tidal conditions. These figures show that the peak daily output of the unit

FIGURE 2-4
MASSET DAILY LOAD AND JUSKATLA TIDAL PLANT OUTPUT
FOR A LARGE TIDE

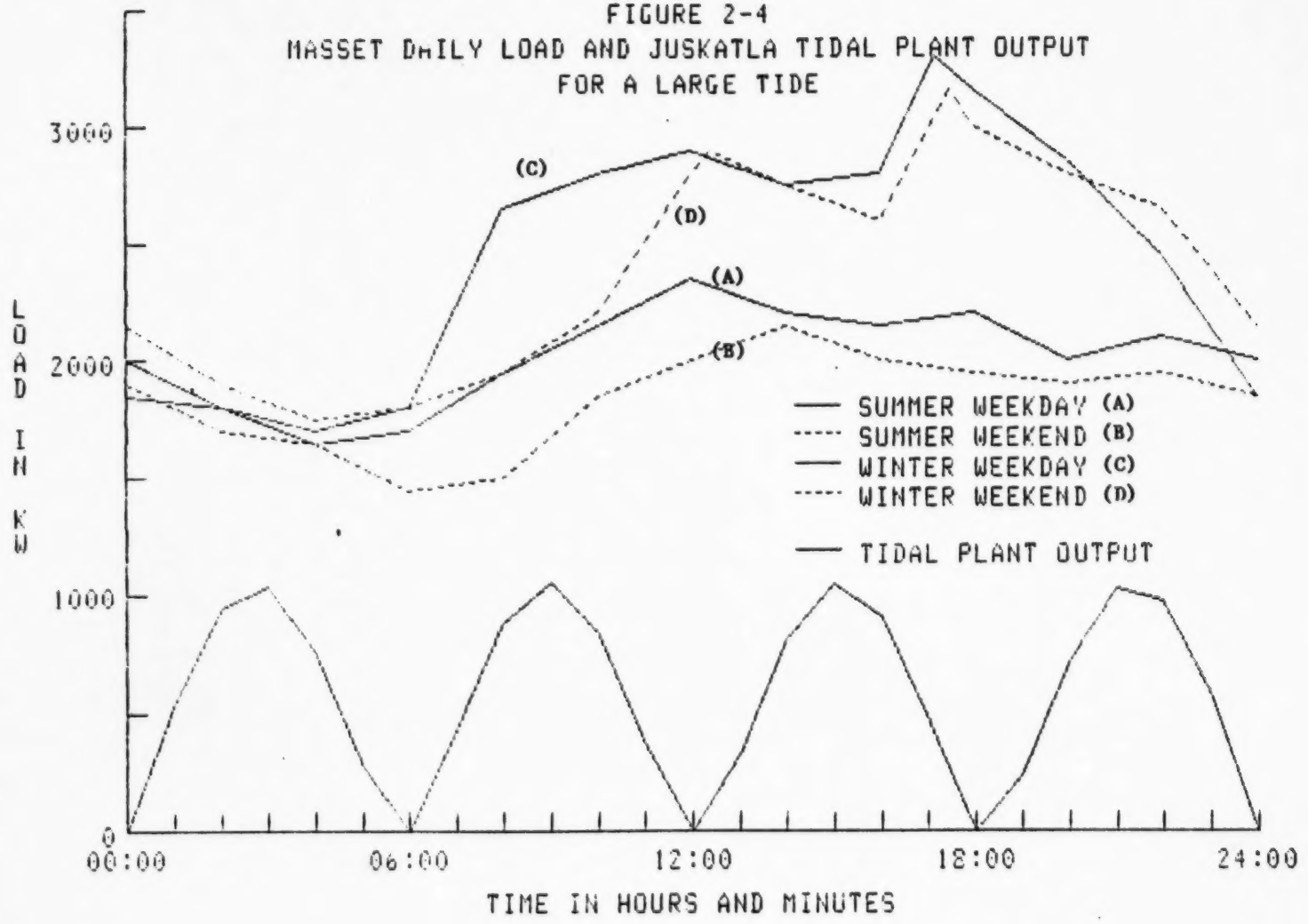


FIGURE 2-5
MASSET DAILY LOAD AND JUSKATLA TIDAL PLANT OUTPUT
FOR AN AVERAGE TIDE

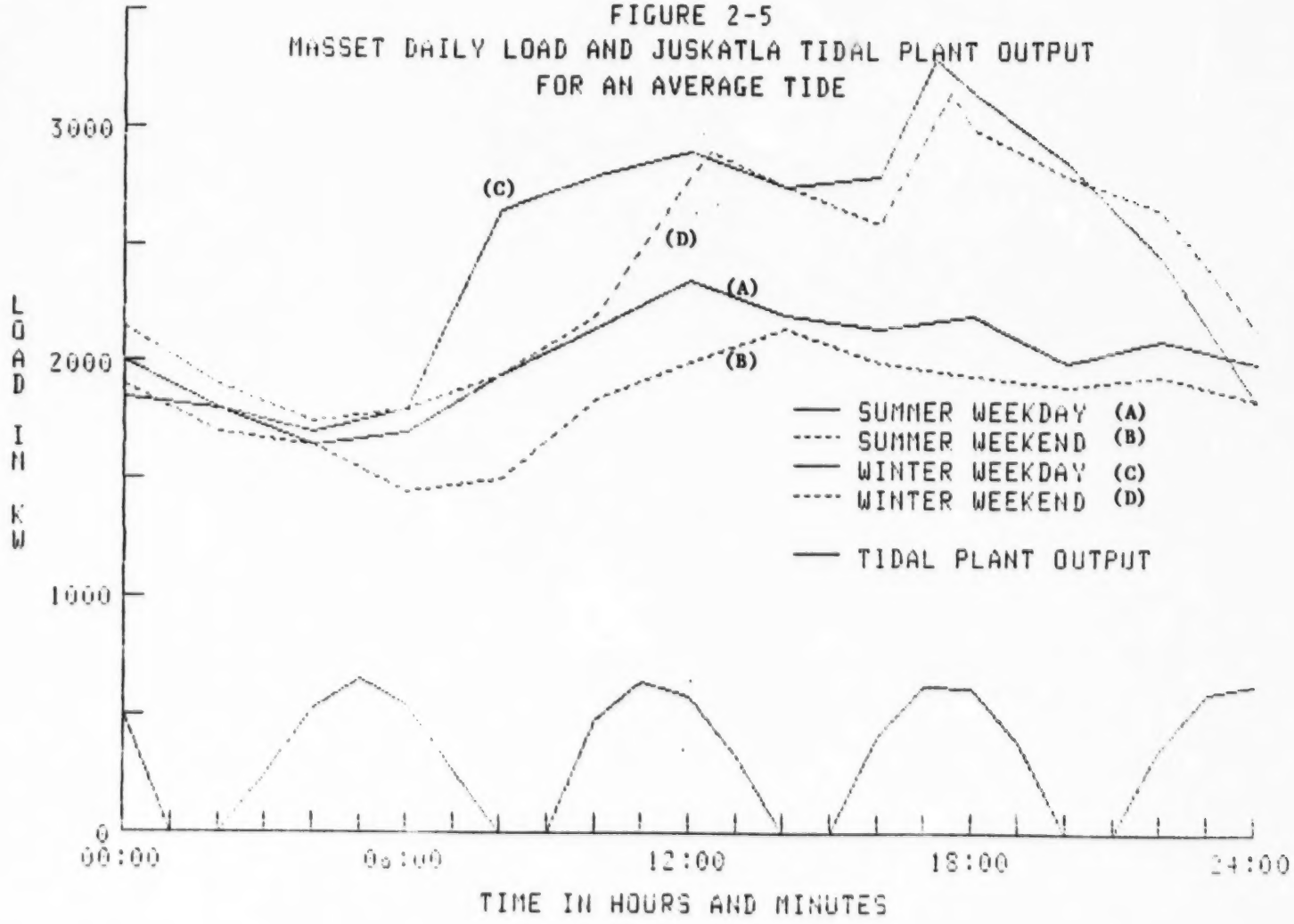
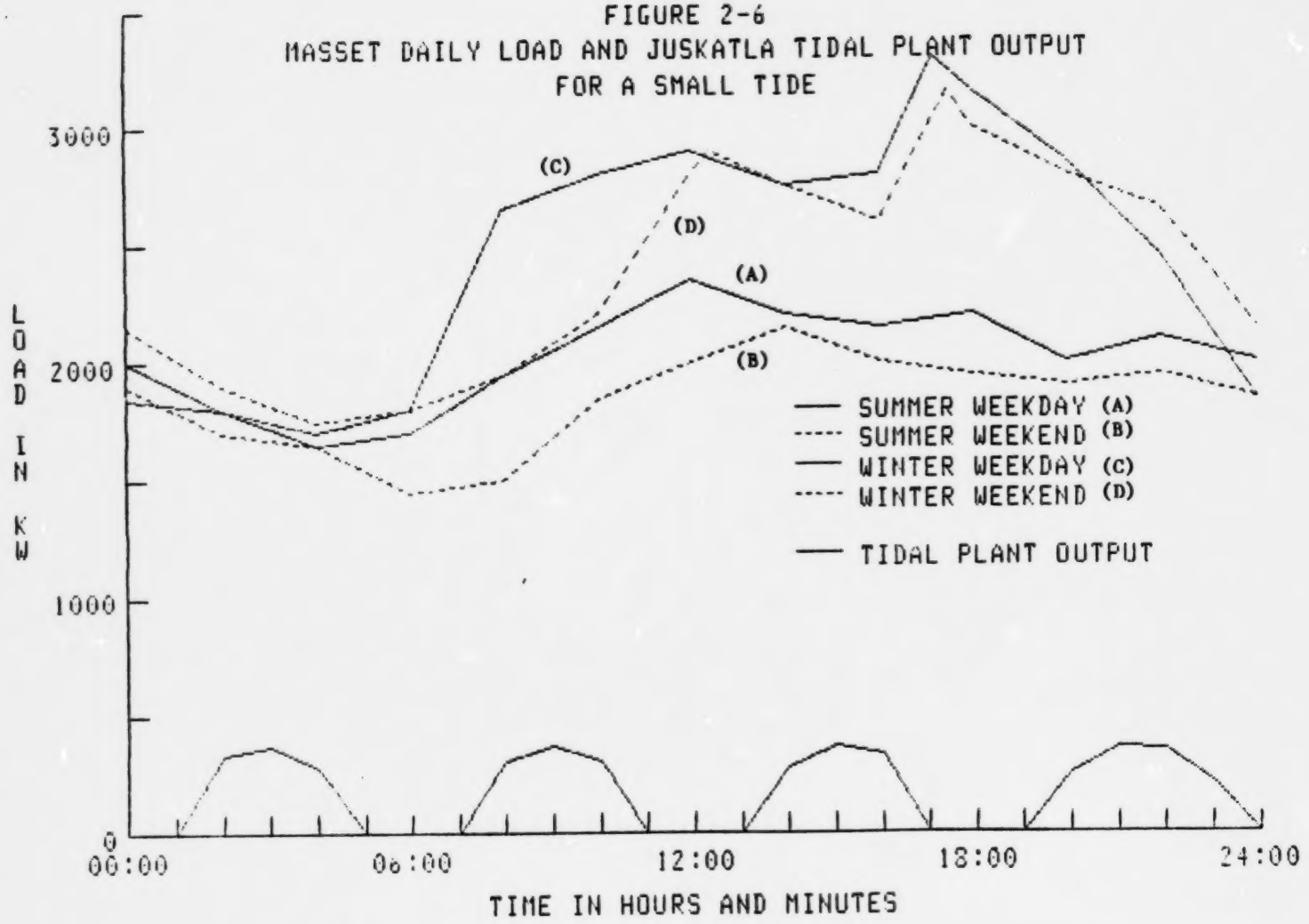


FIGURE 2-6
MASSET DAILY LOAD AND JUSKATLA TIDAL PLANT OUTPUT
FOR A SMALL TIDE



would vary from about 300 kW to 1000 kW. These graphs also indicate that the peak output from the tidal plant would not necessarily coincide with peak loads.

If the second and third units are added to the installation, the plant output would theoretically be 3.6 times the output of the first unit or 12.5 GW·h/a (i.e. 20 percent enhancement due to blockage effects). However, current loads on the Masset grid would often be less than the peak output of the three-unit installation (3600 kW). Thus, some of the energy output could not be utilized unless.

1. The Masset and Sandspit grids were integrated.

2. A major industrial load (e.g. Consolidated Cinola mine) were developed and served by B.C. Hydro.

2.6 CAPITAL COST ESTIMATES

A detailed capital cost estimate for the proposed 1000 kW VAHT installation is presented in Table 2-2. This estimate is based on the cost analysis presented in Section 7.4 of Ref. 2. Transmission and station costs were estimated based on information from B.C. Hydro's System Planning Department. The total capital cost estimate for the initial 1000 kW installation is 8060 k$ (October 1983), excluding interest during construction.

For the ultimate development of three VAHT units, additional costs are estimated as follows:

TABLE 2-2

JUSKATLA NARROWS - 1000 kW VAHT INSTALLATION
CAPITAL COST ESTIMATE

		October 1983 (k$)
1.	Phase I (Preliminary Assessment)	
	Overview study	50
2.	Phase II (Studies and Investigations)	
	Site survey and tidal measurements	50
	Model testing	180
	Program management	150
	Environmental impact studies	200
	Engineering and design	560
	Cost and schedule estimates	60
	Contracts and licences	50
	Production planning	120
	Installation planning	100
	Total Phase II	1470
3.	Phase III (Construction)	
	(a) Generation	
	Site preparation (3 units)	540
	Service dock and pad	250
	Turbine rotor	780
	Duct structure	1170
	Machinery and systems (generator, gearbox, bearings, electrical switchgear, etc.)	450
	Assembly and testing	400
	Delivery and installation	350
	Commissioning	150
	Subtotal Generation	4090
	(b) Transmission	
	Transmission (25 kV to Port Clements)	920
	Station (circuit breakers and transformers)	190
	Telecontrol (from Masset DGS)	250
	Subtotal Transmission	1360
	Total Generation and Transmission	5450
	Contingency and corporate overhead (@ 20%)	1090
	Total Phase III	6540
	Total capital cost*1	8060

*1 Excluding interest during construction.

1.	Phase II costs (studies and investigations)	210 k$/unit x 2 units =	420 k$
2.	Phase III costs (construction)		
	- generation	3300 k$/unit x 2 units =	6,600 k$
	- transmission		1,660 k$
	- substation		80 k$
	- contingency and overhead (@ 20%)		1,670 k$
		Total	10,430 k$

Thus, the total cost estimate for the ultimate development would be 18,490 k$, excluding interest during construction.

2.7 TECHNICAL UNCERTAINTIES

The VAHT turbine is a novel design and differs from other hydraulic turbines in four main ways:

1. The area of the working blades is relatively small and the blades experience high stress levels (e.g. 20 000 psi or more).

2. The blades are subject to oscillating rather than constant loadings.

3. The optimum rpm for a VAHT varies with output.

4. There is no flow control system (e.g. no wicket gates).

Characteristics 1 and 2 indicate that there could be problems with fatigue failure of the blades. The marine environment would tend to accelerate fatigue failure due to corrosion. Nova have indicated that some stainless steels may have adequate fatigue characteristics, but

these would require special corrosion inhibiting coatings. To date, there has been no testing of stainless steel blades under the operating conditions anticipated for the Juskatla unit.

The duct walls could be subject to cavitation effects due to negative pressures generated by the rotor blades (e.g. as occurred on the model installed at Sheet Harbour, N.S.). Nova have indicated that appropriate blade to duct clearances should overcome this problem, but prototype tests are required to verify these calculations.

The rpm output characteristics of VAHT's are similar to those for wind turbines (particularly the Darrieus rotor). Because the VAHT is basically an unregulated, variable output device, special control systems and generating equipment would be required to control output frequency and power. The use of basic synchronous or induction generators would likely not be suitable due to oscillating torque characteristics of the VAHT units and the need for motor run-up. Electronically-controlled generators have been developed for wind turbine applications (e.g. the converter-fed synchronous generator, Ref. 2, Appendix F), but these have not been adapted to VAHT systems. While no special problems are anticipated with generating equipment, prototype testing would be essential prior to the detailed design of a commercial-scale VAHT system.

SECTION 3.0 - PROJECT OPERATION AND ECONOMIC EVALUATION

3.1 ANNUAL COSTS

Annual costs for generation projects consist of three components: capital charges (interest and depreciation), operating costs (operation, maintenance and insurance), and taxes (grants, school taxes, water fees, etc.).

Operation and maintenance (O&M) costs for VAHT units are difficult to estimate because there has been no operating experience with large units (e.g. 500-1000 kW). However, a procedure for estimating the operating costs for hydroelectric installations of similar capacity has been developed (Ref. 5), and this method should be roughly applicable to VAHT units. Annual O&M costs will be small in relation to annual capital charges, thus precise O&M estimates are not critical to the preliminary economic evaluation of the proposed VAHT installation.

Annual costs for the proposed VAHT installation at Juskatla Narrows have been estimated on the following basis:

1. Capital charges are calculated using the capital recovery factor method. An effective interest rate of 4 percent/a (net of inflation) is used per standard B.C. Hydro economic evaluation criteria. The economic life assumed for the VAHT installation is 40 years, similar to that assumed for small hydroelectric units.

2. Operating costs are calculated as a percentage of capital costs. The charge rate adopted for VAHT units is 1.2 percent/a, similar to the charge rate developed for small hydro units (Ref. 5). O&M charge rates for transmission and station facilities are assumed per standard B.C. Hydro procedure.

3. Taxes are estimated based on an annual charge rate of 1.33 percent/a, which primarily covers provincial school taxes. Water fees and other provincial royalty charges are assumed not to apply to tidal projects.

The above assumptions were used in conjunction with the capital cost estimates in Section 2.6 to estimate the annual costs for the proposed one- and three-unit VAHT installations. These annual costs are summarized in Table 3-1.

Based on the annual cost estimates and the annual energy outputs presented in Section 2.5, the unit energy cost for the one and three-unit VAHT installations are estimated to be 190 and 120 mills/kW·h, respectively. These estimates assume that all of the tidal plant energy could be used to serve loads and do not include cost penalties to account for the operation of diesel units at lower, less efficient loadings (see Section 3.2). By comparison, the unit fuel cost at the Masset diesel generating station in 1983/84 was 97 mills/kW·h.

3.2 OPERATION IN CONJUNCTION WITH DIESEL PLANTS

The Masset diesel plant currently comprises three 2100 kW stationary units, one 2500 kW mobile unit and one 600 kW mobile unit. Based on the load curves shown in Fig. 1-2, it appears that most load conditions could be met with one or two 2100 kW units.

Energy generated by the proposed tidal plant would be used to back-off diesel generation and save diesel fuel. The basic effect of this combined operation will be to reduce the average capacity factor of the diesel units. If it is assumed that energy from the 1000 kW VAHT would be used to reduce the output of one 2100 kW diesel unit, the annual capacity factor of the diesel unit would be reduced by 19 percent. Because diesel units have lower fuel efficiencies at lower capacity

TABLE 3-1

JUSKATLA NARROWS - PROPOSED VAHT INSTALLATION
CAPITAL, ANNUAL AND ENERGY COST ESTIMATES
(1983 $)

		1 unit (1000 kW)	3 units (3600 kW)
1.	Capital costs		
	- excluding interest during construction	8060 k$	18 490 k$
	- including interest during construction	8140 k$	18 660 k$
2.	Annual costs		
	- capital recovery	420 k$	970 k$
	- operation, maintenance and insurance	110 k$	250 k$
	- taxes	115 k$	260 k$
	Total annual costs	645 k$	1480 k$
3.	Unit energy costs		
	- total annual costs	645 k$	1480 k$
	- average annual energy*1	3.46 GW·h	12.5 GW·h
	- unit energy cost*1	186 mills/kW·h	118 mills/kW·h

*1 The following assumptions are implicit in the energy and energy cost figures:

a. All of the tidal plant energy could be used to serve loads.

b. No account is made for the increased unit cost of diesel plant operation due to lower capacity factors (see Section 3.2).

factors, not all of the tidal plant energy will translate into fuel savings. Another effect of the tidal plant on the diesel units will be to increase fuel throttle activity to compensate for changes in tidal plant output due to the regular variations in the tides.

Operation at lower capacity factors could lead to coke buildup in diesel exhaust systems creating maintenance and fire hazard problems. This problem was not examined in this study, but should be addressed in any future planning studies.

The effects described above are also encountered when wind turbines are run in parallel with diesel units. Recent studies carried out in the U.S. examined the interaction between a small wind turbine and a diesel system (Refs. 6 and 7). The wind turbine had a peak capacity of 150 kW and was operated in parallel with a diesel system which served a 350 kW average load. One of these studies (Ref. 6) showed that there were no significant control problems (e.g. voltage fluctuations, frequency variations, etc.) associated with the parallel operation of the wind turbine and diesel plant. The situations investigated included startup, normal operation and shutdown of the wind turbine. Because the output from VAHT units would not vary as rapidly as that from wind turbines, no significant control problems are anticipated for the operation of the proposed VAHT unit in conjunction with the Masset diesel plant.

A second study (Ref. 7) developed a procedure for estimating the diesel fuel saving attributable to the wind turbine, taking into account the lower capacity factor operation of the diesel units. The main conclusions of the study were:

1. The rate of fuel displacement by the wind turbine was equal to the incremental fuel consumption rate of the diesel unit used for load/frequency control.

2. Increased diesel engine throttle activity resulting from changes in wind turbine output, does not significantly influence fuel consumption.

3. The wind turbine displaced 13 500 L of diesel fuel during the test period. This represented a 6.7 percent reduction in fuel consumption while the wind unit supplied approximately 11 percent of the total electrical energy to the system.

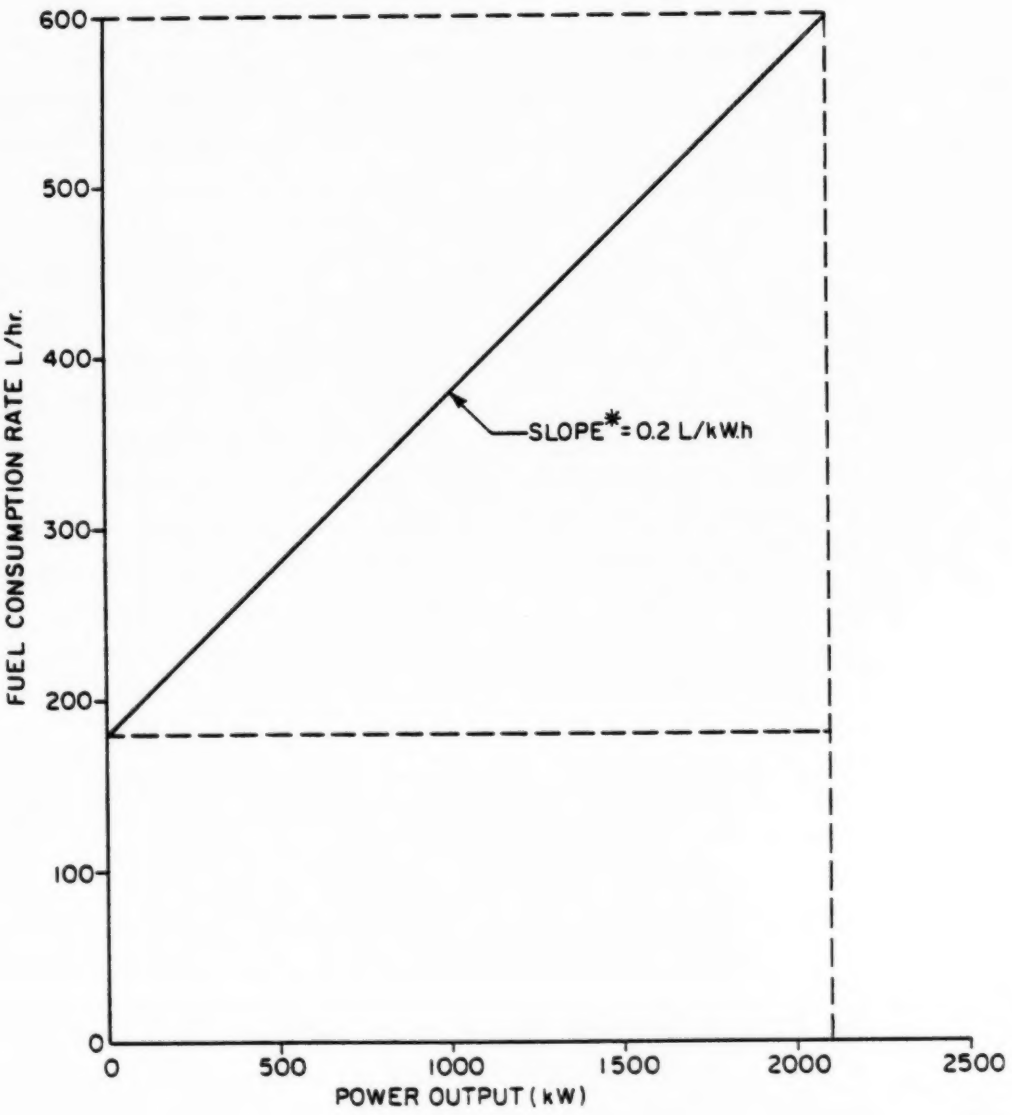
Diesel fuel savings attributable to the proposed 1000 kW VAHT unit can be estimated using a similar procedure. To carry out this calculation, the relationship between fuel consumption and power output for the Masset diesel units must be known. This information for the Masset units was not readily available, but an approximate relationship was estimated based on data presented in Ref. 7 and the fuel efficiency of the Masset plant (see Table 1-2). The relationship is plotted in Fig. 3-1, and the slope of the graph yields the incremental fuel consumption rate. This parameter can then be used to estimate the diesel fuel savings attributable to the VAHT unit according to the following formula:

$$\begin{aligned}\text{Annual diesel fuel savings} &= \text{incremental fuel consumption rate} \times \text{average annual tidal plant output} \\ &= 0.2\ \frac{L}{kW \cdot h} \times (3.46 \times 10^6 kW \cdot h) \\ &= \underline{690\ 000\ L}\end{aligned}$$

The above calculation assumes that the tidal plant output would only be used to back-off the output of the diesel units (i.e. reduce diesel unit capacity factors). However, because tidal output is predictable (unlike wind) it should also be possible to reschedule diesel units so as to achieve more efficient operation.

FIGURE 3-1

ESTIMATE OF FUEL CONSUMPTION VS OUTPUT FOR A 2100 kW DIESEL UNIT



*SLOPE = INCREMENTAL FUEL CONSUMPTION RATE

$$\text{FUEL EFFICIENCY (At Rated Output)} = \frac{2100\,kW}{600\,L/hr.} = \frac{3.5\,kW.h}{L}$$

If perfect diesel unit scheduling were possible (i.e. such that diesel unit capacity factors would be no worse with the tidal plant than without the tidal plant), then fuel savings attributable to the VAHT unit would be calculated as follows:

$$\begin{array}{l}\text{Annual diesel}\\ \text{fuel savings}\end{array} = \begin{array}{c}\text{Average annual tidal}\\ \text{plant output}\end{array} \div \begin{array}{c}\text{diesel unit*}\\ \text{fuel efficiency}\end{array}$$

* Based on operation at normal capacity factor.

$$= (3.46 \times 10^6 \text{kW·h}) \div 3.5 \frac{\text{kW·h}}{\text{L}}$$

$$= \underline{900\ 000\ \text{L}}$$

The actual diesel fuel saving attributable to the VAHT will likely lie somewhere between the above two estimates. However, detailed operating studies would be required to obtain a precise figure. For the purpose of this assessment, the crude approximation of "splitting the difference" will be made. On this basis, the estimated annual fuel saving for the 1000 kW VAHT unit would be 840 000 L.

A similar calculation can be carried out to show that the annual fuel savings for the three-unit, 3600 kW VAHT installation would be 3 040 000 L. However, this saving could only be realized if the Masset and Sandspit grids were integrated or a major industrial load were to be developed and were to be served by B.C. Hydro diesel generation.

3.3 BENEFIT/COST ASSESSMENT

The following tabulation summarizes the annual benefits and costs of the proposed 1000 kW VAHT installation:

1. Benefits

   - annual diesel fuel savings of 840 000 L @ 33.7¢/L — 283 k$

2. Costs

   - annual capital charges, O&M and taxes (see Table 3-1) — 645 k$

Net annual benefits	-362	k$
Benefit cost ratio	0.44	

Based on the above figures, the Juskatla tidal plant appears decidedly uneconomic as an option to reduce diesel fuel consumption at the Masset diesel plant. In order for the project to become even a long-term break-even option for B.C. Hydro (i.e. annual benefits = annual costs), either the cost of diesel fuel would have to increase by 130 percent in real terms or the cost of the project would have to be reduced by 56 percent in real terms.

For the three-unit, 3600 kW installation the benefit/cost relationship improves somewhat as shown below:

1. Benefits

   - annual diesel fuel savings of 3 040 000 L @ 33.7¢/L — 1020 k$

2. Costs

   - annual capital charges, O&M and taxes (see Table 3-1) — 1480 k$

Net annual benefits	-460	k$
Benefit/cost ratio	0.69	

However, the project is still economically unattractive and has the further complication of requiring either integration of the Masset and Sandspit grids or development of a large industrial load on the QCI.

SECTION 4.0 - ENVIRONMENTAL AND SOCIO-ECONOMIC OVERVIEW

4.1 GENERAL

An overview study to identify the expected environmental and socio-economic impacts of the proposed VAHT installation was carried out by B.C. Hydro's Environmental and Socio-economic Services. Resource information for the study was obtained from:

1. Resource data files of MacMillan Bloedel Ltd.

2. Published documentation (e.g. Fisheries and Oceans' reports).

3. Field observations and discussions with local individuals and groups. A list of contacts is provided in Section 4.2(d).

The overview identified concerns expressed by local opinion leaders and assessed the expected impacts of the proposed VAHT installation. In addition, the studies identified shortcomings in available resource information for the purpose of impact assessment of a tidal power development. A program of proposed follow-up studies was outlined. The information summarized below is presented in detail in Ref. 8 along with a complete bibliography.

4.2 SOCIO-ECONOMIC INVENTORY

(a) General Description

Communities and Indian bands on Graham Island were the main focus of the socio-economic overview; in particular Juskatla, Port Clements, Tlell, Queen Charlotte City and Sandspit (Moresby

Island). The Haida Indian communities at Masset and Skidegate were also in the study area.

The Haida Indians were the original inhabitants of the Queen Charlotte Islands and archaeological evidence suggests that inhabitation dates back to 6000 B.C. Euro-Canadians did not settle in the Queen Charlotte Islands until the mid 1800s. At the last official census (1981) the total population of the Queen Charlotte Islands was about 5400 persons of which about 30 percent were Indians.

Regional administration of the Queen Charlotte Islands is provided by the Skeena-Queen Charlotte Regional District in Prince Rupert. The only incorporated municipalities on the islands are Masset and Port Clements.

(b) Economic Base

The major economic activity on the Queen Charlotte Islands is logging and the principal companies are Crown Forest Products, MacMillan Bloedel, Rayonier and Cipa. There are some locally-owned wood processing plants, but most of the raw logs are shipped elsewhere for processing. The forest resources of the Queen Charlotte Islands represent about 8 percent of the B.C. total.

Commercial fishing and tourism represent significant seasonal activities on the Queen Charlotte Islands. There are also some minor amounts of agriculture (vegetables, berries) and manufacturing (wood production, fish processing).

A number of development opportunities exist which could expand and diversify the economy of the Queen Charlotte Islands. Consolidated Cinola Mines Ltd. have completed a feasibility study and pilot evaluation of a large gold mining prospect south of Port Clements.

Offshore oil and gas exploration in Hecate Strait is anticipated in the near future. These and other possible developments are discussed in more detail in the community descriptions below.

(c) Community Descriptions

Masset, which is at the northern end of Graham Island, is the largest community on the Queen Charlotte Islands (1981 population of 1569). Access to Masset is via highway and ferry from Sandspit, float aircraft or tug and barge service from Prince Rupert. The main economic activities are commercial fishing and the B.C. Packers cannery. The Canadian Armed Forces have a base near Masset which employs 200 military personnel and 60 civilians. Masset appears to have good potential for tourism development.

Queen Charlotte City is located at the southern end of Graham Island and the 1981 census population was 1070. The principal economic activities in Queen Charlotte City are logging and commercial fishing. The Indian community of Skidegate is located nearby and is the terminus for B.C. Ferry service from Prince Rupert.

Sandspit, at the northwestern end of Moresby Island, has the only major airport on the Queen Charlotte Islands. The 1981 population was 754. The main sources of local employment are either the federal Ministry of Transport or Crown Forest Products. Sandspit could be a likely base for offshore oil and gas exploration.

Tlell is a small rural community on the eastern side of Granam Island. There is some agricultural and ranching activity in this area.

Port Clements is located on Masset Inlet about 50 km south of Masset. It is the closest community to the proposed tidal site and

had a 1981 population of 380. The community began as a mining townsite in the early 1900s, but is now mainly a settlement and service community for MacMillan Bloedel's nearby logging operations. MacMillan Bloedel's operation is based at Juskatla which is about 12 km southwest of Port Clements. The community of Port Clements would probably become the base for the proposed Consolidated Cinola gold mine, should it proceed. Port Clements also appears to have some prospects for tourism development.

Haida Indian communities on Graham Island comprise Haida (north of Masset) and Skidegate (east of Queen Charlotte City). As with other Queen Charlotte Islands' communities, employment is mainly in either logging or fishing. The total population of the Masset and Skidegate Indian bands was 1589 in 1983. The Haida are noted for their Indian artwork and carvings, and many artists are still active on the reserves.

People on the Islands generally share a strong identification with the Queen Charlottes and appear to be polarized in their attitude toward development. Even those that recognize the advantages of tourism or mineral development, are cautions and want to ensure that all environmental and social considerations are taken into account.

(d) Individuals/Groups Contacted

Mary Morris) Brian Eccles)	-	Kallahin Expeditions, Queen Charlotte City
Tom Hackin	-	Regional District Representative
Jim Betteridge	-	B.C. Hydro employee
Gerry Johnson	-	Major, Port Clments Chairman, Graham Island Advisory Planning Commission

Malcom Dunderdale	-	Senior Forestry Engineer, MacMillan Bloedel
Dave Penna	-	Mayor, Masset
Margo Hearn	-	Alderperson
Charlie Bellis	-	Alderperson
Lyle Endreud	-	Fisheries, Masset
Art Collison	-	Salmon Enhancement Program, King Creek
Ruth Stewart-Burton	-	Alderperson
Michael Nicholl	-	Advisor to the Masset Band
Doug Leach	-	Editor, Queen Charlotte Islands Observer
Miles Richardson	-	Manager, Skidegate Band, and Executive Chief, Council of the Haida Nation
Vicki Sexsmith	-	Manpower Counsellor, President, Islands Protection Society
Bob Olson	-	United Fishermen and Allied Workers Union
Bill Lindsey	-	Planner, Skeena-Queen Charlotte Regional District
Bryce Barnewall	-	Clerk, Port Clements
Terry Dyer	-	District Manager, Queen Charlotte Forest Service
Bill McCaveney	-	B.C. Hydro, Queen Charlotte Islands, District Manager
Mike Parrish	-	B.C. Hydro, Queen Charlotte City Office
Sandra Eastwood	-	Recreation Director, Manager Port Clements

Gerry Williams	-	Chief, Masset Band
Gary Klohn	-	B.C. Hydro, Chief Operator, Sandspit Diesel Generating Station

4.3 ENVIRONMENTAL INVENTORY

(a) Aquatic Environment

Juskatla Inlet and its tributary streams are utilized by several anadromous fish, including Pacific salmon (pink, sockeye, coho and chum), sea-run cutthroat trout, steelhead and sea-run Dolly Varden char. Herring also migrate into Juskatla Inlet to spawn. Resident species in tributary streams include trout (rainbow and cutthroat) and Dolly Varden. The Mamin River is the largest tributary to Juskatla Inlet. A natural falls limits anadromous fish migration spawning to the lower 13 km of the river. Although logging activity appears to have had some impact on the river's characteristics, it has an abundance of spawning substrate and a high capability for fish production. Coho and pink salmon appear to be the main species in the Mamin and annual escapements for each species vary from less than 100 to several thousand. The river also supports minor numbers of sockeye (i.e. annual escapement less than 100). Steelhead, rainbow trout, cutthroat trout (sea-run and resident), and Dolly Varden char are also present in the Mamin River. Other tributary streams which provide habitat for salmon and other anadromous species are Slingshot, Dean and Datlamen creeks. In general, coho salmon appear to be most prevalent in these streams. Several other small, unnamed streams appear to offer good spawning habitat for salmon and other anadromous fish.

The strong tidal action and the relative abundance and diversity of benthic organisms near Juskatla Narrows are conducive for feeding by cutthroat trout and Dolly Varden. A large run of cutthroat trout appear to feed in Canoe Passage. Benthic organisms in

Juskatla Inlet are relatively diverse and abundant, particularly in intertidal areas. Several different species of clams are found in and around Juskatla Narrows and Canoe Passage. Also abundant are blue mussels, sea urchins, cockles, bull kelp and kelp crabs. Dungeness crabs, shrimps and prawns are found throughout Juskatla Inlet. Large intertidal areas supporting various benthic organisms are found near Ferguson Bay in Masset Inlet.

The only commercial fishing carried out in Juskatla Inlet is for shrimps and prawns. There are no commercial fish or mariculture farms in Juskatla Inlet.

(b) Terrestrial Environment

The forest around Juskatla Inlet is typical of the entire Queen Charlotte Islands. The principal tree species are western hemlock, sitka spruce and western red cedar. The area north and east of Juskatla Inlet has already been logged extensively, and further timber leases are held on the area northwest of Juskatla Inlet (Mt. Begbie). Road access to this area is difficult and would require construction of a bridge across Juskatla Narrows. At present, there are no plans to proceed with the bridge or logging in the area.

Coastal black-tailed deer are prevalent in all areas around Juskatla Narrows, although no specific information on distribution and numbers are available.

Various migratory waterfowl (ducks, geese) use portions of Juskatla Inlet as rest areas during migration. Nesting geese have been observed on Fraser and Deasy Islands. Trumpeter swans, glaucous-winged gulls and peregrine falcons have also been observed in portions of Juskatla Inlet.

Seals are found through Juskatla Inlet and some sea lions may also enter the inlet. Whales enter Masset Sound but none have been observed in Juskatla Inlet.

(c) Heritage Resources

Inhabitation of the Queen Charlotte Islands began sometime before 6000 B.C. These people established campsites where they subsisted primarily on shellfish. By 1500 B.C. semi-permanent village sites had been established and tools of ground stone and bone were in use. From 1500 B.C. to 1774 A.D. (the date of first contact with European explorers) the archaeological record is that of the ancestors of the Haida people. Euro-Canadian inhabitation of the Queen Charlotte Islands began in the mid 1800s.

There are at least seven archaeological sites near Juskatla Inlet. These sites are near-shore and comprise middens of crushed shells, aboriginal villages and canoe construction sites.

(d) Recreation

Sport fishing for salmon, shrimp and crabs are the principal recreation activities in Juskatla Inlet. Angling also takes place in some tributary streams, but is limited by access. Fraser Island and Mamin Bay are recreation areas for clam digging, camping, fishing and hunting (deer and geese). Other recreation opportunities in the inlet include wilderness camping and rockhounding.

Logging roads around Juskatla Inlet provide access for hunting, although there are some shooting restrictions. A boat launch is located at Juskatla.

4.4 IMPACT ASSESSMENT

(a) Socio-economic Impacts

The project is expected to employ about 45 people over a 3-year period. Since most of the positions require highly technical skills, local employment would be limited. A few local resident may obtain employment on the clearing contract for the transmission line. However, spending by the workforce would inject $1.6 million dollars into the local economy.

Generally, the local population expressed support for the concept of tidal generation as a means to reduce diesel fuel consumption. However, concern was expressed about possible impacts of the project on aquatic resources in Juskatla Inlet.

Other concerns and queries which were expressed by local people related to the site selection process, employment opportunities during construction and operation, studies of other generation options, B.C. Hydro's commitment to alternative energy development, and local involvement in future studies. A comprehensive public information and consultation program would be essential to any further studies of the proposed tidal plant. In summary, the project has the potential for creating positive social and economic benefit if it is planned in such a way as to be compatible with the Island's lifestyle.

(b) Aquatic Environment

Evaluation of impacts on the aquatic environment is difficult because there are no pertinent operational data for VAHT units. A VAHT installation could impact aquatic organisms in several ways including:

1. Obstruction of fish and marine mammal movements through Juskatla Narrows.

2. Mortality or injury caused by impact with rotating blades. Such impacts are expected to be less than those for conventional turbines due to the low rpm and high blade to duct clearances for the VAHT units.

3. Delay of anadromous fish migrations into Juskatla Inlet.

4. Reduction of salt water intrusions into tributary streams due to changes in the tidal range in Juskatla Inlet. This effect could influence spawning activity in these streams.

5. Construction activities (e.g. noise) may drive off fish and marine mammals. Drilling for placement of concrete pylons could generate siltation levels which may adversely affect local populations of bottom-dwelling organisms (e.g. clams, crabs, etc.)

Insufficient information is available to judge the significance of the above impacts. However, it is obvious that impacts for a single VAHT unit would be substantially less than for three units because one unit would cause less blockage of the Narrows and less change in the Juskatla Inlet tidal range.

The impacts of the proposed VAHT installations on boat navigation through Juskatla Narrows and water quality in Juskatla Inlet are expected to be minor in view of the relatively small amount of boat traffic and the fact that less than one-third of the Narrows would be taken up by the tidal power installation.

(c) Terrestrial Environment

Project construction activities would have some minor impacts on the terrestrial environment. Construction noise would disturb deer, waterfowl and other birds in the immediate vicinity (e.g. nesting geese on Fraser and Deasy islands). Transmission line construction from Juskatla Narrows to Port Clements would require clearing of about 10 ha of forest land. Line construction would also cause some short-term disturbance of wildlife but in the longer term the right-of-way would provide additional browse vegetation for deer.

(d) Heritage Resources

Construction of the proposed VAHT installation should not disturb any heritage sites since all major construction work could likely be conducted on the water. Impact of transmission line construction on heritage sites on Fraser Island and possibly other yet unidentified sites could be avoided by careful route selection and construction practices.

(e) Recreation

Recreation opportunities around Juskatla Inlet should not be affected by the proposed VAHT installation. Some short-term increase in fishing and hunting activity would be anticipated during the construction period.

4.5 FURTHER STUDIES

The studies listed below would have to be conducted as part of further feasibility investigations of a VAHT installation in Juskatla Narrows.

(a) Socio-economics

This work would comprise a socio-economic profile of the main communities and development of programs for impact assessment and consultation with local communities and Indian bands.

(b) Aquatic Environment

Inventory components of this work would include identification of salmon and other anadromous fish in Juskatla Inlet, description and assessment of fish migration patterns in the area, and identification of numbers and types of benthic organisms in the vicinity of Juskatla Narrows. Impact assessment would focus on the potential for fish mortality and injury in passing through VAHT turbines. Construction impacts on benthic organisms would be assessed.

(c) Terrestrial Environment

Wildlife studies would comprise an inventory of the abundance and distribution of deer habitat in areas which would be affected by transmission line construction. Waterfowl stopover, nesting and staging areas in Juskatla Inlet should be surveyed. Vegetation types and sensitivities to disturbance on proposed transmission right-of-ways would be identified. Other inventory work would include documentation of current and proposed land use and information on hunting efforts and harvest in the general area. Impact assessment would focus primarily on vegetation and wildlife impacts due to transmission line construction.

(d) Heritage Resources

Potential heritage sites on proposed transmission routes would be surveyed.

(e) Recreation

An inventory of current and planned recreation resources and usage should be conducted in the immediate area of the project.

SECTION 5.0 - FURTHER TECHNOLOGY DEVELOPMENT AND PLANNING STUDIES

To proceed with the planning and development of a VAHT unit at Juskatla Narrows, further major studies and investigations would be required as outlined in Phase II shown on Table 2-2. Nova Energy have estimated that the cost of additional studies for the initial 1000 kW VAHT would be in the vicinity of 1500 k$ (Ref. 2, Section 7.4). The main components of this work would be as follows:

(a) Technology Development

This work would include design and model studies to address technical uncertainties and assess the performance characteristics of large-scale VAHT units. Particular emphasis would be on materials selection, stress analysis, cavitation effects, selection of electrical generation equipment and output control systems. Support work would include obtaining technical site information such as tidal current measurements, water samples, geological data, surveying, etc. The studies and investigations described above would be staged such that technology development work would be carried out before initiating the planning and detailed engineering phases. Technology development studies are estimated to cost about 300 k$ (50 k$ for site measurements, 180 k$ for model testing and 70 k$ for related design studies).

(b) Planning Studies

This work would include technical aspects such as further evaluation of project economics, detailed assessment of the coordinated operation of the VAHT and diesel plant, and further system studies (e.g. transmission, control and protection

requirements). In addition, comprehensive environmental and socio-economic impact studies as defined in Section 4.5 would be required. A community relations program to inform and seek local community input would also be essential. A specific cost estimate for this work has not been prepared.

(c) Detailed Engineering

This work would include detailed engineering and design, production and installation planning, detailed cost estimates and schedule. Based on Nova Energy's estimate, this work would cost about 1000 k$.

SECTION 6.0 - CONCLUSIONS

1. Preliminary studies indicate that the capital cost of the 1000 kW VAHT unit proposed for Juskatla Narrows would be 8060 k$ (excluding interest during construction). For three VAHT units of the same design, the capital cost would be 18 490 k$.

2. The annual energy outputs from the proposed one- and three-unit VAHT installations were estimated to be 3.46 and 12.5 GW·h/a, respectively. This power output would fluctuate with tide changes on a semi-diurnal basis.

3. The proposed VAHT units would be physically large, having a rotor diameter of 9.75 m and a rotor blade length of 9.25 m. By comparison the largest working VAHT model has a rotor diameter of only 2.4 m.

4. Economic analysis indicates that the proposed VAHT tidal plant would be substantially more expensive than existing diesel generation at Masset. For a single 1000 kW VAHT unit, the estimated annual fuel saving would be 840 000 L which is equivalent to 283 k$ at 1982/83 fuel prices. By comparison the annual costs of the VAHT installation are estimated to be 645 k$ based on a 4 percent net interest rate. For a three-unit VAHT installation the annual diesel fuel saving would be equivalent to 1020 k$ compared to annual costs of 1480 k$. Thus, either substantial real increases in diesel fuel costs or substantial reductions in VAHT unit costs would be required to make VAHT units economically competitive with diesel generation.

5. The proposed VAHT installation should not cause any significant control problems (e.g. voltage or frequency fluctuations) for the

Masset diesel plant. The main effect of the tidal plant on the diesel units will be increased operation of the diesels at lower capacity factors.

6. Based on the current status of VAHT technology, there are still significant uncertainties regarding the commercial feasibility of VAHT systems. The main technology issues which need to be addressed are operational reliability, cost effectiveness and structural integrity.

7. Overview-level environmental studies indicate that installation and operation of the proposed 1000 kW VAHT unit should have no major environmental impacts. However, more information is required on the ability of fish and marine mammals to pass through VAHT units without injury. General public support for the proposed project can be anticipated, provided careful attention is given to environmental issues and local public input is solicited.

SECTION 7.0 - RECOMMENDATIONS

1. Technology development work discussed in Section 5.0 (e.g. model tests) should be funded by a research agency such as the Canadian Electrical Association or the National Research Council. B.C. Hydro could consider secondary participation in the program by offering assistance in obtaining site data (e.g. current measurement, water samples, surveying) or possibly providing in-house design expertise to review results of model and design studies. The scope of model studies should possibly be expanded to include preliminary evaluation of mortality and injury effects of VAHT units on fish and marine mammals.

2. Planning and detailed engineering studies discussed in Section 5.0 should be held in abeyance pending results of model tests and other technology development work.

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